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RESPONSES OF STURGEON TO SOUND - PRELIMINARY RESULTS

Report No 87-302-K

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ABSTRACT

Preliminary experiments were conducted in a semi-anechoic tank (15.5 mL x 15.5 mW x 1.5 mD) on the responses of Lake sturgeon (Acipenser fulvescens) to various frequencies and amplitudes of sound. Sound was generated using an impact device (hammer) which produced a high amplitude, low frequency, impulsive sound (20 - 1000 Hz). Results indicated no marked avoidance of a single sound device irrespective of frequency. There was also no marked response by the majority of fish when subjected to several operating sound devices. The hammer sound device has probably little potential for repelling Lake sturgeon from intake structures.

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34-165-401	837.315	March 31, 1988	87-302-K

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EXECUTIVE SUMMARY

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Environmental assessment studies conducted on the Mattagami River in Northern Ontario indicated the possible concern that lake sturgeon could be stranded in Adam Creek after passage through the spillway. To minimize stranding or possible losses of sturgeon from the Little Long headpond, a fish diversion study was initiated.

Preliminary experiments were conducted in a semi-anechoic tank (15.5 mL x 15.5 mW x 1.5 mD) on the responses of sturgeon (Acipenser fulvescens) to various frequencies and amplitudes of sound. Sound was generated using an impact device (hammer) which produced a high amplitude, low frequency, impulsive sound (20 - 1000 Hz). Results indicated no marked avoidance of a single sound device irrespective of frequency. There was also no marked response by the majority of fish when subjected to several operating sound devices. The hammer sound device has probably little potential for repelling Lake sturgeon from intake structures.

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To Dr. W.R. Effer
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RESPONSES OF LAKE STURGEON TO SOUND - PRELIMINARY RESULTS

1.0 INTRODUCTION

The use of low frequency impulsive sound as a management tool to divert or repel fish away from a specific area has considerable potential (Haymes and Patrick 1986, McKinley and Patrick 1986). Sound propagates well underwater; the speed of sound is 4.8 times faster in water than in air. It consists of two components, a pressure wave and a particle displacement associated with the sinusoidal pattern of the sound waves. Both of these components can be perceived by the acoustico-lateralis system of a wide variety of fish (Popper and Coombs 1981, Blaxter and Hoss 1981).

Environmental assessment studies conducted on the Mattagami River in northern Ontario indicated a possible concern that sturgeon could be stranded in Adam Creek after passage through the spillway. To minimize stranding or possible losses of sturgeon from the Little Long Headpond, Ontario Hydro initiated an investigation of possible fish diversion measures. At a request from the Environmental Studies and Assessments Department (File 962-192-07010), a proposal was prepared to determine the responses of Lake sturgeon to various frequencies of sound as a potential mitigative measure. Although sturgeon are a primitive species, some of the early literature has suggested that sturgeon may be sensitive to sound (Harkness and Dymond 1961). Based on our preliminary laboratory findings, a recommendation will be made concerning further research involving sound as a means of controlling sturgeon movement.

2.0 MATERIALS AND METHODS

2.1 Species to be Investigated

Approximately fifty small Lake sturgeon (Acipinser fulvescens, 1-3 Kg) were collected from the Blind River area of the North Channel, Lake Huron and transported by Cool Water Farms Ltd to our research laboratories in Toronto. Unfortunately, fish were in poor condition as a result of excessive handling at the collection site. No attempt was made to feed these fish which were held under controlled temperature and lighting conditions. After the laboratory tests were completed all surviving fish were returned to the original collection site.

2.2 Sound Source

Experiments were conducted using the hammer or fishpulser sound deterrent. The hammer is an electromechanical device which produces a repetitive sharp sound of relatively high amplitude sound pressure by exciting resonant vibration modes of a structure which is in direct coupling

with the surrounding water (McKinley and Patrick 1986). It produces an impulsive sound which has a duration of approximately 200 ms (time to decay by a factor of 10). The device is capable of generating different fundamental frequencies ranging from approximately 20 to 1000 Hz (with minimal modification). If sturgeon are capable of responding to an impulsive sound created by the hammer device, a response was expected to occur within this frequency range.

2.3 Test Facilities

Experiments were conducted in a square, semi-anechoic tank (15.5 mL x 15.5 mW x 1.5 mD) which has been constructed specifically for work involving sound (Figure 1). A concrete wall was installed along the inside perimeter of the tank to minimize sound reverberations. A wall has also been constructed which divides the tank into two sections (although not distinct). The hammer(s) was positioned in one corner of the experimental half of the tank. In all remaining outside corners (3), dummy hammer devices were positioned to remove any visual reference to the real hammer device. Observations were made both visually and by the use of closed circuit TV. Six cameras (including a camcorder) were placed both above and below the water to track and observe fish behaviour in response to the the sound stimulus.

2.4 Experimental Design

The intent of these tests was simply to determine whether this species would respond to sound and to assess the roles of both frequency and amplitude in eliciting a marked fish avoidance response. Information was obtained on the presence or absence of fish observed in each of the sixteen sections of the tank (Figure 1).

Experiments consisted of tests of 5 minutes duration to determine the fundamental sound frequency and amplitude for optimum response. Five different frequency patterns were evaluated which were produced by changing the thickness of the end plate. (Changing the plate thickness is only one of many ways to alter the signal output). Although the frequency patterns were generally broad band, there were at least two fundamental frequencies for each plate thickness (Table 1). For example, a 6.3 mm plate produced fundamental frequencies of 70 and 400 Hz. Generally, an increase in end plate thickness resulted in higher fundamental frequencies. The sound pressure levels estimated approximately 3 m from a single hammer were similar for each end plate (except the 9.5 and 15.9 mm plates which were slightly lower). In experiments where more than one hammer was used, the energy levels were expected to increase at least proportional to the number of hammers employed. All levels used in the protocol were expected (based on the responses of other species) to elicit a fish behavioural response if one occurred. All experiments were conducted under simulated dusk conditions (<0.1 uE m^{-2} s^{-1}).

For convenience, the hammer frequency patterns employed will be referenced in the test by the thickness of the various end plates that were used to create those frequencies: 6.3, 7.9, 9.5, 12.7 and 15.9 mm. In all experiments, the hammer(s) was operated at approximately 26 pulses/minute.

Three replicates were conducted for each plate thickness. In approximately half the tests, the position of the hammer was alternated to avoid potential bias of fish preference for one section of the tank over another. Ten fish were used in each replicate. Because of the poor condition of fish, animals were changed frequently for each series of tests. In addition, control tests were also conducted for each experimental treatment to determine fish distribution and movement prior to when the sound source was turned on. Data were collected simultaneously on both sections of the tank.

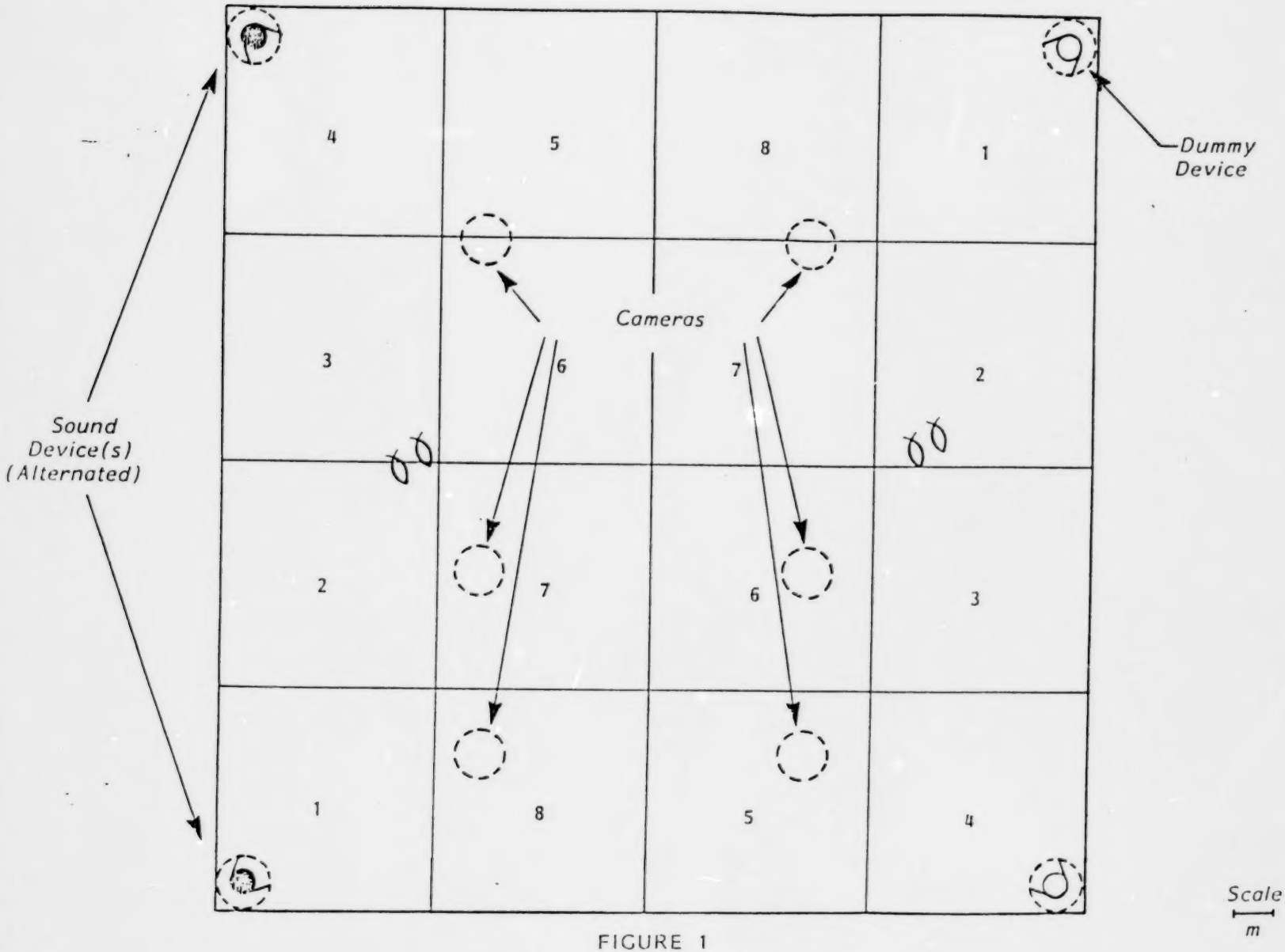

FIGURE 1
EXPERIMENTAL TEST FACILITY
(15.5m L, 15.5m W, 1.5m D)
(Eight Control and Experimental Zones)

Table 1:

Estimated
Fundamental Frequencies and Sound
Pressure Levels for Various End Plates
of the Hammer Sound Deterrent

Plate Thickness (mm)	Estimated Fundamental Frequencies (Hz)	Sound Pressure Level at 3 m x +/- S.D. (kPa)
6.3	70,400	13.5 (1.3)
7.9	80,500	14.3 (1.1)
9.5	110,600	11.7 (0.9)
12.7	123,550,800	13.1 (1.4)
15.9	168,550,700	11.1 (estimated)

2.5 Data Analysis

Observations were made both visually and by the use of closed circuit TV. Observations of the presence or absence of fish in each of the sixteen sections of the tank were made over thirty, consecutive, ten second time periods, yielding a replicate of 5 minutes duration. No distributional assumptions were made since the minimum and maximum points for each section were 0 and 30, respectively, and the data could be clustered at any extreme. In addition, the consecutive time periods were not independent of each other since a school may not necessarily move out of a particular section by the next time period. The non-parametric Kruskal-Wallis method was therefore used to evaluate the data since it requires no assumption about the distribution of data. Comparisons were made of the number of occurrences of fish at both the two closest (3.5 m x 7.0 m area) and four closest (7.0 m x 7.0 m area) sections of the tank nearest the sound source. Since the sample size was small (in most cases three replicates for each treatment) the power of the procedure was limited. In the data analysis, the thirty time periods were therefore split into two components of fifteen time periods each.

3.0 RESULTS AND DISCUSSION

3.1 Effects of Frequency and Amplitude of Sound on Fish Behaviour

During control tests, fish either were positioned on the bottom or were swimming slowly in the centre of the tank. When the hammer(s) was turned on, some individuals displayed an erratic swimming behaviour moving either quickly towards or away from the operating devices. Reasons for this behaviour are unclear.

There was, however, no evidence that fish showed a marked avoidance of the hammer sound deterrent for the different frequencies examined (Figures 2 and 3). The mean number of counts was actually slightly higher for most plate thicknesses than observed in the controls (although not statistically different at $p < 0.01$). Similarly, with several hammers in operation, there was no evidence of a marked response (although the mean counts were slightly lower in the experimental treatments than the controls in the three hammer tests, not statistically significant, Figure 3). Some individual fish were noted to avoid the immediate vicinity of the hammers. These results suggest that a low frequency impulsive sound does not show much promise for repelling sturgeon.

The absence of a marked response by sturgeon to the hammer may not be surprising given the ecology of this species. Sturgeon are a bottom dwelling species which feeds primarily on bottom substrate and benthic organisms. Food is searched by constant movement close to the bottom and by the sensory ability of the barbels (Scott and Crossman 1973). There is probably little need for a sensitive sound system involving these foraging activities. Similarly, since the number of predators on lake sturgeon appears limited, there is no need for an elaborate hearing system as a means of avoiding predation. A dissection of a test specimen indicated the absence of an elaborate hearing system (eg no weberian ossicles) for perceiving sound. Harder's (1975) review of the anatomy of fishes suggests that the sturgeon have a primitive hearing system. Sound perception by the sturgeon may occur through the skin and/or cartilage.

4.0 RECOMMENDATION

Results from this study suggest that further research involving the hammer device as a deterrent is not warranted. However, this does not mean that all research involving sound or another behavioural stimulus should be curtailed. It is important to understand why fish pass over the spillway into Adam Creek. Further research should be conducted on fish behaviour in the vicinity of the spillway. If passage occurs primarily at night, perhaps lights could be used as a deterrent.

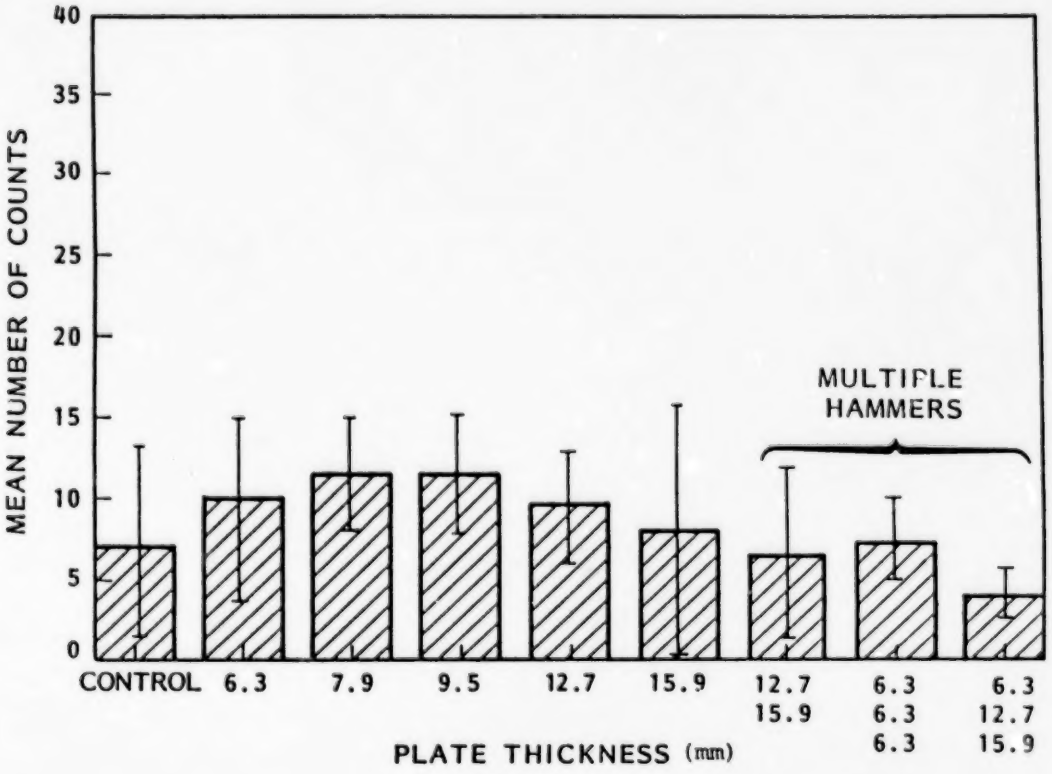

FIGURE 2

MEAN NUMBER OF STURGEON OBSERVED IN TWO SECTIONS (3.5 m X 7.0 m) OF THE TANK CLOSEST TO THE HAMMER DURING CONTROL AND EXPERIMENTAL TESTS

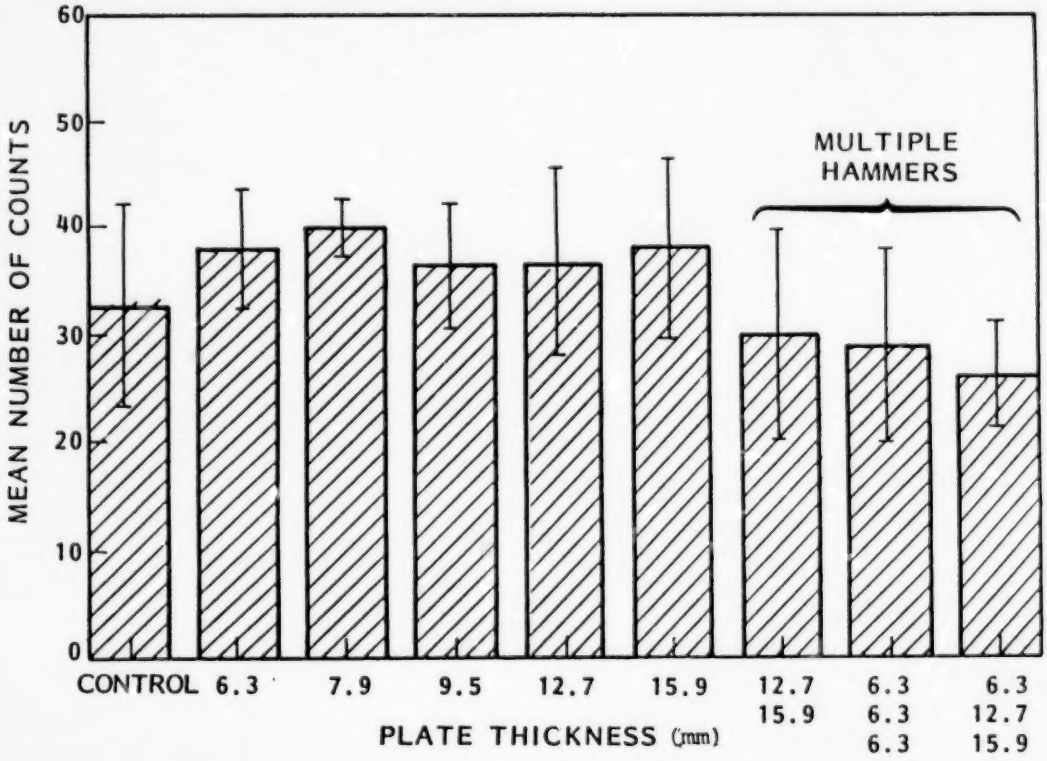

FIGURE 3

MEAN NUMBER OF STURGEON OBSERVED IN FOUR SECTIONS (7.0 m X 7.0 m AREA) OF THE TANK CLOSEST TO THE HAMMER DURING CONTROL AND EXPERIMENTAL TESTS

5.0 ACKNOWLEDGEMENTS

Fish were collected by commercial fisherman E. and E. Carlson of Blind River, and transported to our laboratory by Cool Water Farms Ltd. I thank J. Neil and G. Kamaitis of Cool Water Farms and W. Samis of the Ministry of Natural Resources for their efforts. I also acknowledge the technical assistance of S. Poulton and V. Stonkus. I also thank J. Forest of the Mechanical Research Department for his work involving the hammer device. Acoustical measurements were also taken by J. Forest. C. Bartlett of Operations Research analyzed the data.

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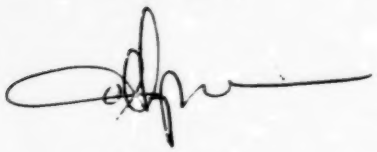

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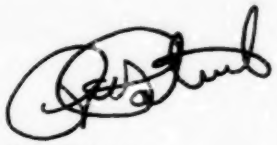

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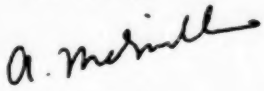

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